NASA AMES
Virtual Airspace Modeling and Simulation (VAMS)

Air Traffic Management System Development &
Integration (ATMSDI)

Model Tests and Verification Examples for ACES Build 2.0

11 February 2004

ACES Build 2.0 Features

- **Increased capability to measure the impact of system constraints with five new airspace models**
  - En route congestion and resolution
  - Airline Operation Center flight delay and cancellation
  - Horizontal Conflict Detection and Resolution
  - Surface traffic limiters
  - User-adjustable runway capacities
- **Concept-specific modeling for Advanced Airspace Concept**
  - Allows analysts to describe the safety and capacity implications of the higher density sector utilization implied by this concept
  - Targets long-term goal of directly simulating new concepts
- **Selected architectural enhancements**
  - Decreased simulation time, for a full day in the NAS scenario, by a factor of six over previous builds
  - Provides increased usability along with fidelity

# Approach to Model and Simulation Testing and Verification

- Build 2.0 adds nearly 70,000 new actual lines of source code for models and infrastructure

- Development process includes reviews and tests
  - Engineering design reviews
  - Software design reviews
  - Software Test Documents

- Released software versions undergo additional validation
  - Comparison with data
  - Comparison with other simulators
  - Evaluation by subject matter experts

- Presentation highlights four test examples

Enroute Congestion

This set of enhancements provides the capability in ACES to perform flight delays based on enroute sector overloads.

We performed tests focusing on the following areas:

- Monitor Alert functionality

- Congestion Resolution Planning

- ARTCC Exit Boundary Crossing Restrictions

- ARTCC Sector Traffic Overloads

- Stability (large case scenario)

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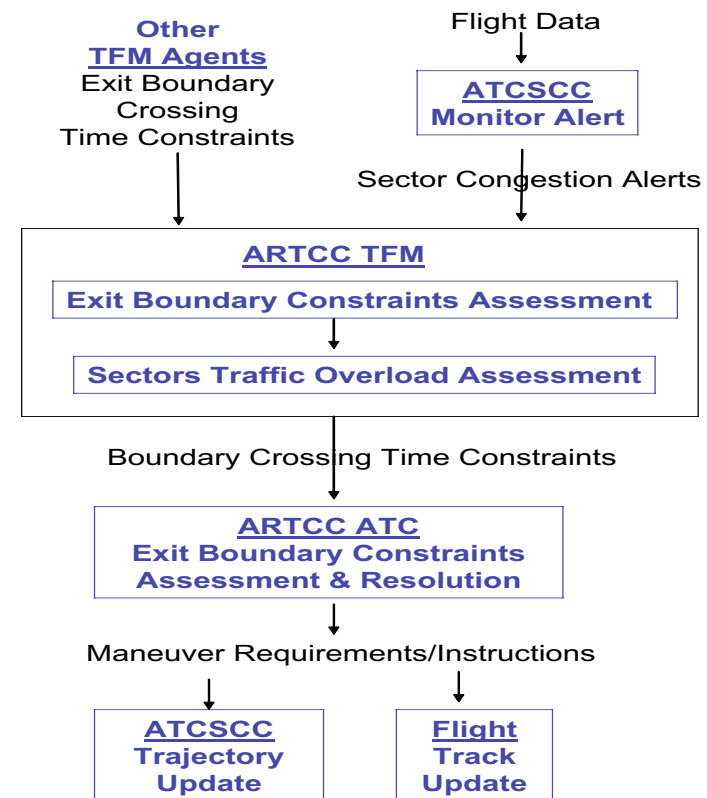
Enroute Congestion

This test verifies that the sector assessment algorithm can handle differing transit times.

Flights	Scheduled Times		Planned Times		Actual Times	
	Entry	Exit	Entry	Exit	Entry	Exit
AAL462	5:58:14	6:10:25	5:58:14	**6:10:25**	5:58:14	6:10:25
UAL8031	6:03:00	6:14:30	6:03:00	**6:14:30**	6:03:00	6:14:30
AAL463	6:05:14	6:17:25	**6:10:25**	**6:22:36**	6:10:05	6:22:15
UAL8032	6:07:00	6:18:30	**6:14:30**	6:26:00	6:13:55	6:25:25
UAL8033	6:11:00	6:22:30	**6:22:36**	6:34:06	6:21:51	6:33:20

Unit Test 4 times for ZID83
Sector Capacity 2, 5 Flights Overload, Differing Transit Times

- The ARTCC TFM plan is for the third flight to enter as the first flight exits, the fourth flight to enter as the second flight exits, and the fifth flight to enter at the third flight's revised exit.

- Looking at the scheduled times, the AAL flights have transit times of 12:11 and the UAL flights have transit times of 11:30. These are preserved throughout the table.

- The Actual Times differ as the maneuvers are based on a 4 DoF model that allows for variations in flight time.

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Airline Operations Center (AOC)

The AOC model specifies flight delays and cancellations to meet airline specific goals across the NAS.

We performed tests focusing on the following areas:

- AOC input parameters
- Hub airports and banks identification
- AOC flight cancellation functionality
- AOC flight delay functionality

AOC Test Example

The simulation is set-up with sequence of flights arriving at two airports LAX and PHX. Flights listed in the table below were delayed by the Scenario to induce the AOC operation.
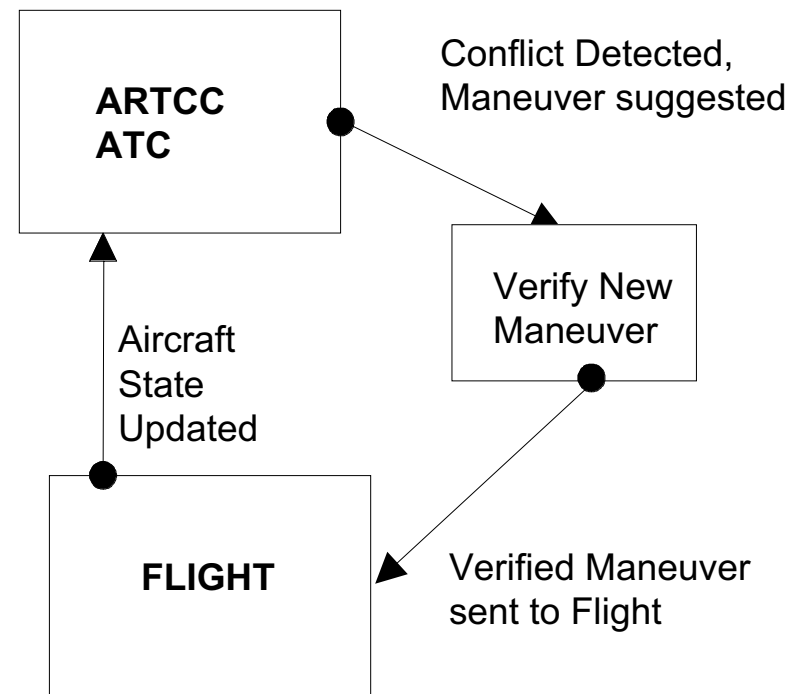
Flight	From	To	Delayed	Scheduled gate arrival	Delayed gate arrival
AWE487	DEN	PHX	4 hours 20 min	5:30:00	9:50:00
AWE275	RNO	PHX	1 hour	8:52:43	9:52:43
AWE51	ABQ	PHX	1 hour	8:56:05	9:56:05
AWE126	LAS	PHX	2 hours 40 min	7:16:48	9:56:48
AWE426	SLC	PHX	3 hours 24 min	6:32:41	9:56:41
AWE1402	EWR	LAX	1 hour 20 min	6:12:16	7:32:16
AWE1041	LAS	LAX	1 hour 50 min	4:18:03	6:08:03
AWE1915	SFO	LAX	1 hour 20 min	5:19:56	6:39:56
AOC Delayed Flights					
AWE315	LAX	PHX	60 min	9:00:51	10:00:51
AWE536	LAX	PHX	60 min	9:02:51	10:02:51
AWE402	LAX	PHX	60 min	9:09:53	10:09:53
AWE173	LAX	PHX	60 min	9:19:52	10:19:52
AOC Cancelled Flights					
AWE487	DEN	PHX			
AWE426	SLC	PHX			
AWE126	LAS	PHX			

Conflict Detection & Resolution

The ARTCC ATC model performs a tactical conflict detection computation for all aircraft pairs and maneuvers one of the aircraft to achieve at least the minimum separation at the point of closest approach.

We performed tests focusing on the following areas:

- The vectoring algorithm against multiple conflict geometries
- Aircraft flying at different speeds
- High winds
- Stability (e.g., multiple simultaneous conflicts at the same time / location)
- Special conditions (e.g., no maneuver if aircraft is too close to ARTCC boundary)
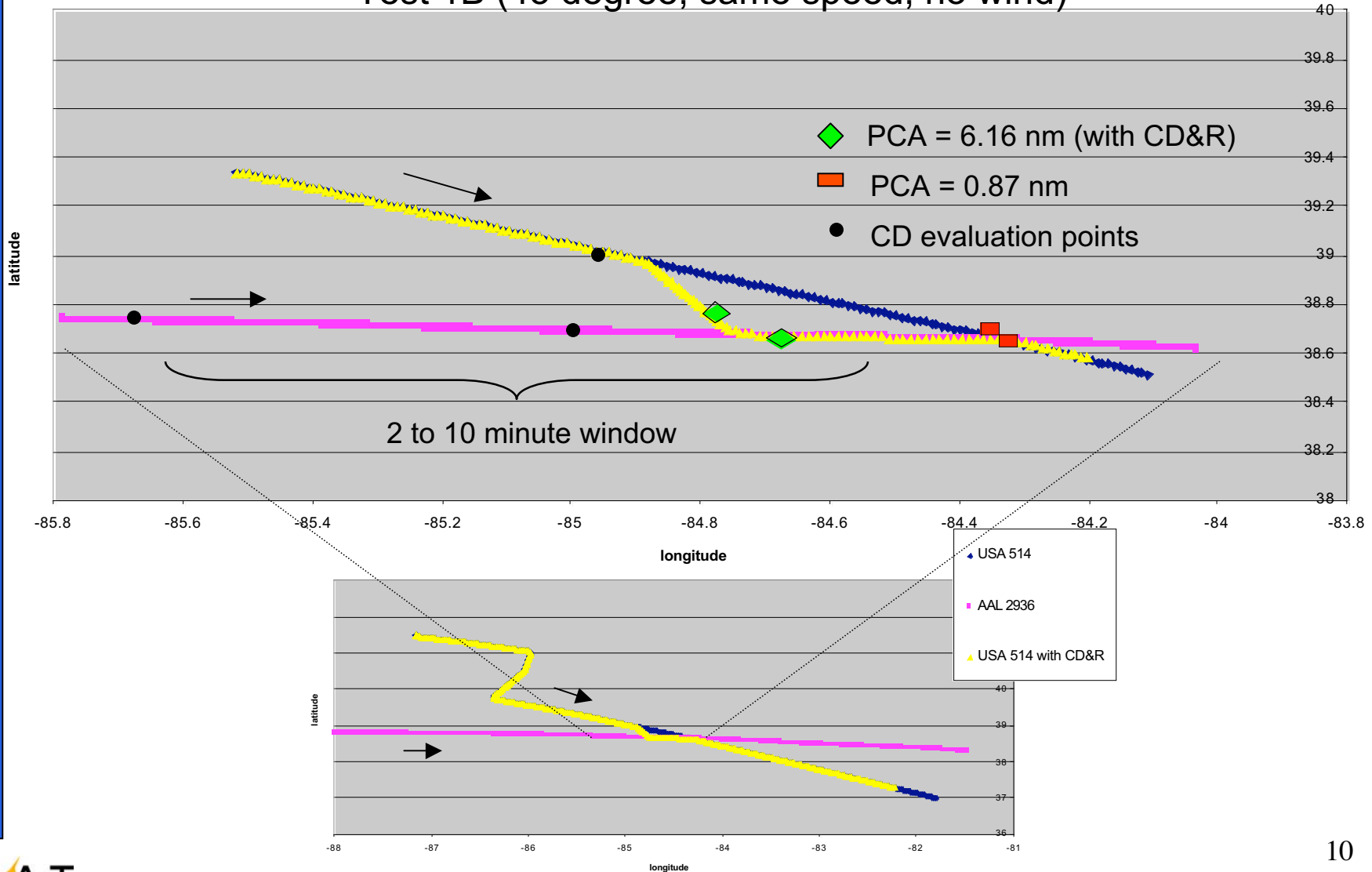
ARTCC ATC

Conflict Detected, Maneuver suggested

Verify New Maneuver

Aircraft State Updated

FLIGHT

Verified Maneuver sent to Flight

Conflict Detection & Resolution

Basic Test Configuration / Description	Conflict Approach Angle (degrees)	AC #1 ID	AC #1 Speed (knots)	AC #2 ID	AC #2 Speed (knots)	AC manuevered	Measured Conflict spacing (nm)	CD&R result (nm)	Comment
2 flights, same speed, no wind, vary conflict									
	10	DAL 997	455	NWA 1750	455	DAL 997	0.77	3.46	
	10	DAL 997	455	NWA 1750	455	DAL 997	0.83	3.46	
	45	USA 514	455	AAL 2936	455	USA 514	0.86	6.19	
	90	NWA 857	455	DAL 997	455	NWA 857	1.1	5.7	
	135	USA 514	455	AAL 2936	455	USA 514	1.15	6.05	
	170	DAL 997	455	NWA 1750	455	DAL 997	1.51	6.83	both AC maneuver
	180	DAL 997	455	DAL 998	455	DAL 997	0.4	6.41	

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Conflict Detection & Resolution

Test 1B (45 degree, same speed, no wind)

◆ PCA = 6.16 nm (with CD&R)

■ PCA = 0.87 nm

● CD evaluation points

2 to 10 minute window

- USA 514
- AAL 2936
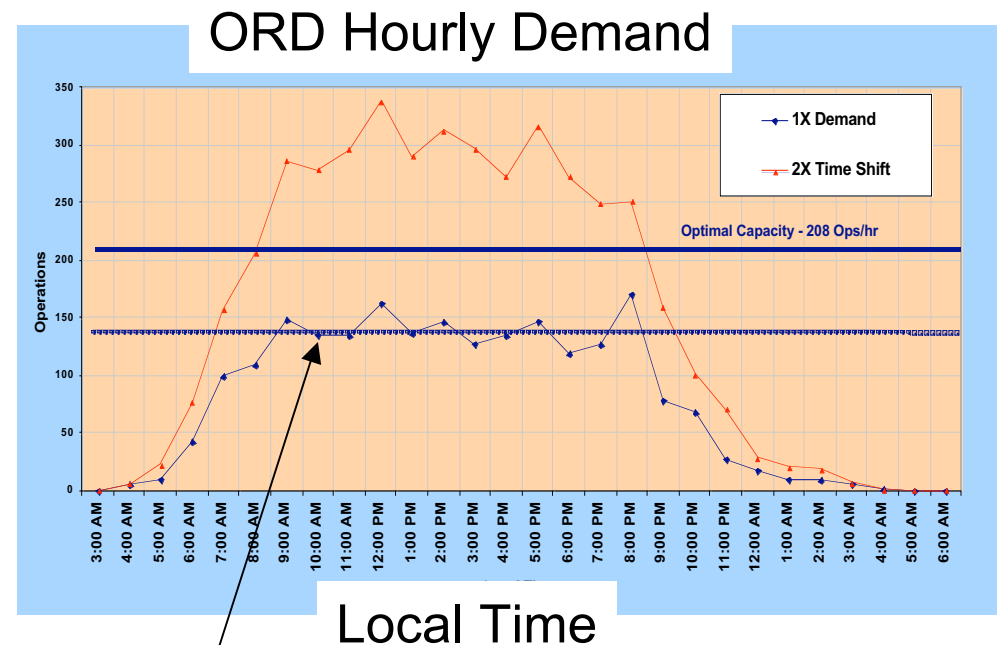- USA 514 with CD&R

System-Level Tests

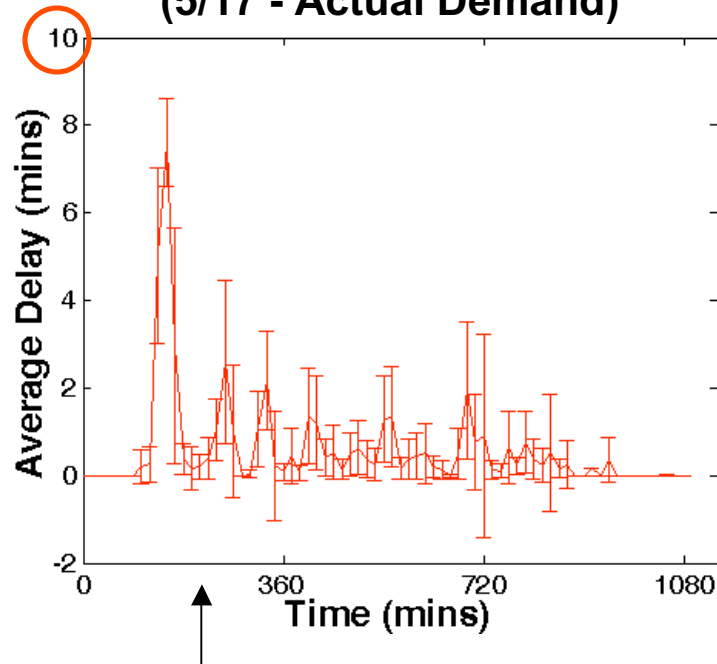**The delay at Chicago O'Hare is examined for various traffic demands.**

Traffic Demand:

- Used actual data for May 17, 2002

- Doubled the demand for May 17th

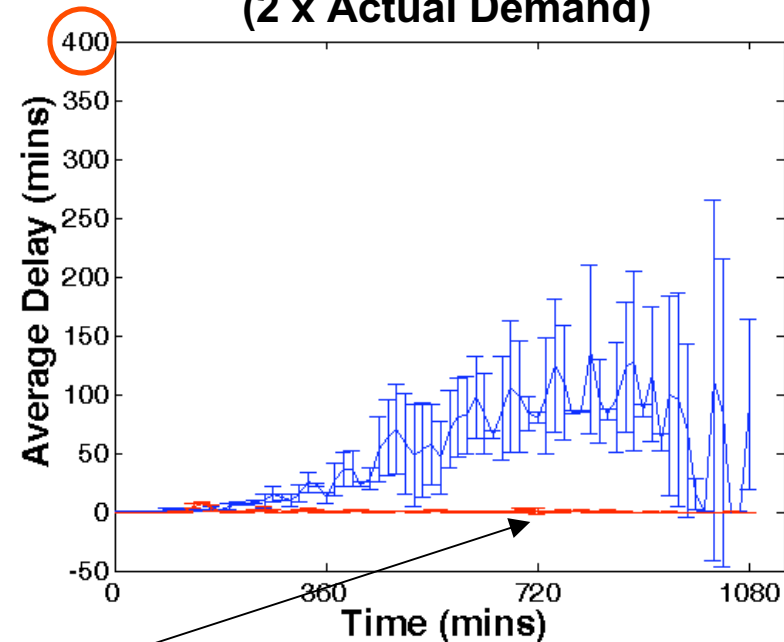 (Some flights shifted out for capacity adjustment up to one hour)

ORD Hourly Demand

Local Time

Baseline Demand

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O'Hare Gate Arrival Delays

Simulation Gate Arrival

(5/17 - Actual Demand)

Simulation Gate Arrival

(2 x Actual Demand)

5/17 arrival delays for Chicago O'Hare

Average delay increases from accumulation of more aircraft in the queue.

NOTE: The AOC is NOT canceling flights in this run.

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Summary of Completed Testing for ACES Build 2.0

- New features integrated within Build 2.0
  - Developed 10 enhancements to 7 models
  - Developed 4 system interface enhancements
  - Met 61 functional requirements
- Tests verified each new feature
  - Conducted 123 model specific tests
  - Conducted 20 system and integration tests
- Presentation illustrated some specific tests
- Upgraded software installed within ACES Lab for further validation

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